PSYCHROMETER MEASUREMENTS

PROCEDURE ID: YMP-LBNL-TIP/AFT 6.0 | REV. 2, MOD. 0 | EFFECTIVE: 08/25/2000

1. PURPOSE

This Technical Implementing Procedure (TIP) describes the methods to assure the accuracy, validity, and applicability of psychrometers used by the Yucca Mountain Site Characterization Project (YMP) at Lawrence Berkeley National Laboratory (LBNL).

This procedure describes the methods used for psychrometer calibration, operation, and performance verification. In addition, it defines the requirements for data acceptance, documentation, and control; and it provides a means of data traceability.

2. SCOPE

This procedure applies to all LBNL personnel (or contractor personnel following LBNL procedures) involved in YMP data collection activities using this procedure, and any equipment calibration or re-calibration activities that may be required. These activities are subject to the Quality Assurance Requirements and Description (QARD), DOE/RW-0333P. Prior to conducting work described in Section 3.0 of this procedure, personnel require training to this procedure.

All technical activities including data collection using this procedure and any equipment calibrations or recalibrations that may be required shall be in accordance with this TIP and in full compliance with YMP Administrative Procedure (YAP)-12.3Q, *Control of Measuring and Test Equipment and Calibration Standards.* Documentation resulting from actions taken under this TIP shall be recorded in Scientific Notebooks as described in the Office of Civilian Radioactive Waste Management (OCRWM) Administrative Procedure (AP)-SIII.1Q, *Scientific Notebooks*. Electronic data maintenance, controls and transfers shall comply with YMP-LBNL-Quality Implementing Procedure (QIP)-SV.0, *Control of the Electronic Management of Data.*

If this procedure cannot be implemented as written, YMP-LBNL personnel shall notify the responsible Principal Investigator (PI) or designee. If it is determined that a portion of the work cannot be accomplished as described in this TIP, or would produce undesirable results, that portion of the work shall be stopped and not resumed until this procedure is modified per YMP-LBNL-QIP-5.2, *Preparing Development Plans & Quality /Technical Implementing Procedures.*

If the responsible PI or designee determines that a modification or a revision to the TIP would cause an unreasonable delay in proceeding with the task, then an expedited change to the procedure, including documentation of deviation from the approved procedure, can be made according to YMP-LBNL-QIP-5.2. Such changes are subject to review, usually after the task has proceeded, and thus work performed under TIPs with expedited changes is done at risk of future invalidation.

Employees may use a controlled electronic or hard copy of this procedure; however, employees are responsible for assuring that the correct revision of this procedure is used. When this procedure becomes obsolete or superseded, it shall be destroyed or marked "superseded" to ensure that this document is not used to perform work.

3. PROCEDURE

Calibrated psychrometers shall be used to help determine subsurface water potentials at Yucca Mountain, as part of a cooperative effort to characterize the potential repository site.

3.1 Materials and Methods Used

Wescor Peltier cooled psychrometers with stainless steel screens, operated by a CR7 data logger (Campbell Scientific) are the two main components of the water-potential measurement system. The calibration of the water-potential measurement system consists of performing measurements of samples of known water potential.

Solutions of NaCl or KCl are generally used in the calibration. Tables are available which give the relationship between water potential and molality for solutions of these salts (Brown 1970). A comprehensive review of thermocouple psychrometery/hygrometry is described by Spanner (1951), Campbell et al. (1973), Brown and Collins (1980), Savage et al. (1983), and Savage and Cass (1984).

3.1.1 Identification Tag

All psychrometers shall be given a unique identification number which shall be taped onto the two ends of the psychrometer cable. This identification number shall be documented in the scientific notebook. All psychrometers used for measurement of water potentials will be placed on the Measurement and Test Equipment list.

3.1.2 Cleaning of Psychrometers

The psychrometer thermocouple, mount, and screen shall be thoroughly cleaned before any calibration and before being used for measurements.

The stainless steel screen psychrometers shall be cleaned by rinsing them vigorously in distilled de-ionized water. Water shall also be forced into the screen shield by placing the nozzle of a plastic squeeze bottle directly on the screen and forcing the water from the bottle into the screen.

3.1.3 Connection to the CR7 data logger

Psychrometer cables have an outer insulation of white PVC. Enclosed are an aluminized mylar shield with a bare drain wire, two insulated copper conductors (one red and one black) and an insulated constantan conductor (blue).

Details of the connections between the psychrometers, datalogger (Campbell Scientific, model CR7), and a Psychrometer Cooling Current Interface (Campbell Scientific, model A3497) are provided in Attachment 1. Location of psychrometers in the datalogger shall be documented in the scientific notebook in accordance with AP-SIII.1Q, *Scientific Notebooks*.

3.1.4 Computer Software

PC208W (Campbell Scientific) software is used to make measurements of water potential using the psychrometer and datalogger . (Software version should be recorded in notebook). The format for the programming instructions is outlined in the operator's manual for the CR7 and the instruction manual for the A3497 Cooling Current Interface. The software is an integral part of the measuring and test equipment and is controlled by YAP-12.3Q, *Control of Measuring and Test Equipment and Calibration Standards*. The program used to calibrate psychrometers and to measure water potentials in the field shall be documented in the scientific notebook.

Attachment 2 provides an example of a program to measure 10 psychrometers with one CR7 datalogger.

3.2 Psychrometer Calibration and Data Conversion

Calibration is required as a part of this technical procedure. All instruments and / or instrument systems shall be calibrated in compliance with the YAP-12.3Q.

All calibrations, unless otherwise specified, shall be performed according to manufacturer's range and accuracy specifications.

3.2.1 Standards to be used

A three-point calibration is required to be performed in LBNL before the psychrometers are used for measurements. (A four to six point calibration can also be done over a range to increase confidence of measurement at that range).

For the three-point calibration 0.1, 0.5, and 1.0 molal solutions of KCl are prepared. To prepare a 0.1 molal of KCl, 7.455 g of KCl (NIST traceable) are dissolved in 1.0 kg of water. To prepare a 0.5 molal solution of KCl, 37.275 g of KCl (NIST traceable) are dissolved in 1.0 kg of water. To prepare a 1.0 molal solution of KCl, 74.550 g of KCl (reagent grade) are dissolved in 1.0 kg of water.

3.2.2 Calibration Method

A. To calibrate, immerse the psychrometers in a known concentration of KCl , having a known water potential (i.e. 0.1 molal KCl has a water potential of -4.59 bars, 0.5 molal KCl has a water potential of –22.28 bars, 1.0 molal KCl has a water potential of -44.49 bars) (Brown, 1970). Allow sufficient time for vapor equilibrium to occur within the shield (about one hour) between calibration steps. Calibration details shall be documented in the scientific notebook.

B. Temperature corrections

The psychrometric method is highly dependent on the temperature. The standard procedure is to adjust all calibrations and measurements to a temperature of 25^0C using the following formula (see Attachment 4: P55 Series Psychrometers):

Corrected reading = (Measured reading) / (0.325 + 0.027T) [1]

Where T is the temperature in celsius at which the reading was made.

Note because of the large error bar associated with psychrometer measurements the temperature reading in the psychrometer is not required to be NIST traceable.

C. Data output and transformation

The data output from each psychrometer as written in the program outlined in Attachment 2 is restricted to 31 columns in a single row. Output of each psychrometer is included in a separate row. The sampling interval determines the frequency of measurements. The first row of data from each time step included a unique row identifier (Column 1), year (Column 2), Julian day (Column 3), time in hours and minutes (Column 4), ambient temperature in ^{0}C (Column 5), and output voltage from data logger battery (Column 6).

The first column for each row of psychrometer data is a unique identifier for that particular psychrometer. The second column records the temperature measured by the psychrometer. Columns 3 to 31 record voltage output measured by the datalogger.

For calibration of psychrometers and for determining water potential values, data from the 3rd column of voltage data (i.e. fifth column of the data along each row) shall be used along with the corresponding temperature data which are recorded in the second row.

The voltage output from the 3rd column of voltage data is the measured reading and the corresponding temperature data in Column 2 is the temperature (t). Equation [1] shall be used to correct for temperature effects. This corrected reading shall then be used to calibrate psychrometers or determine water potentials.

Plot the temperature corrected voltage values against the corresponding water potential values of the calibration solutions. Calibration solutions must include output from three or more concentrations ranging between 0.01 and 1.0 molal of KCL. Use linear regression to output slope and intercept value.

The output voltage recorded in the 5th column for each psychrometer output is the indicated water potential value from calibrated psychrometers. First correct for temperature by Equation [1]. Then water potential is given by:

Water potential = (corrected reading * A) + B

Where 'A' and 'B' are the calibration coefficients (i.e. slope and intercept).

D. Quantitative / Qualitative Criteria

Water-potential data shall be collected with psychrometers that demonstrated linear outputs during the three (or more) point calibration procedure. Multiprocessors (CR7) shall be accurate to, but not limited to, about 20 nanovolts.

The Principal Investigator or designee shall be responsible for validity and applicability of psychrometer data for water-potential interpretations.

Qualitative criteria for acceptance of data include, but are not limited to, the presence of a clear plateau in the plot of the psychrometer output data (Attachment 3). Failed psychrometers shall be discarded.

3.2.3 Manufacturer's Recommendation for Storage and Handling

When not in use the psychrometer tips shall be kept covered to prevent contamination.

3.2.4 Tolerances and Range of Use

The functioning range of the psychrometers is between 0 and -700 m

3.2.5 Calibration Interval

Psychrometers shall be calibrated once, prior to installation. Psychrometers installed in the field are generally not retrievable.

3.3 Assumptions Affecting the Procedure

The assumptions affecting this procedure are tied to the limitations; see Section 3.5 for further explanation.

3.4 Documentation of Data Information

All psychrometer output data files(from calibrations and field measurements) shall be logged in a scientific notebook and shall include psychrometer location, observer, date, time, station name, time of reading. Output data from calibrations and field measurements shall be downloaded from the data logger (CR7) and stored on an active and back-up computer hard-drive. Downloaded data shall be checked in a

spreadsheet to verify that all data from psychrometers being measured has been collected. The check shall be indicated in the scientific notebook. Data will be controlled in accordance with YMP-LBNL-QIP-SV.0

A summary of the documentation to be included is as follows:

- the unique ID of the psychrometers calibrated
- date calibrated
- calibration data
- no documentation on recalibration due date or calibration interval / frequency is necessary as psychrometers will be calibrated prior to installation only.
- identification of this procedure (including revision level) used to calibrate the psychrometers
- identification of and traceability to the calibration standards used for calibration
- results of the calibration and statement of acceptability
- no documentation is necessary on as-found condition because psychrometers found to be out of compliance during calibration will be discarded
- the specified range of calibration shall be documented. If the psychrometers do not produce an output during the calibration procedure or if the tolerance is exceeded then the psychrometer shall be discarded.
- personnel performing calibrations

Note: nonconforming psychrometers shall be identified in the scientific notebook and discarded.

Maintenance of all calibration records described above may be done by a contributing investigator under the direct supervision of the PI. Otherwise these will be maintained by the PI. The documentation of each calibration will be forwarded to the Record Processing Center (RPC) in accordance with YAP-12.3Q and the M&TE custodian at LBNL.

3.5 Limitations

Psychrometers are sensitive to variations in the ambient temperature. Psychrometer measurements during periods of large temperature fluctuations shall be discarded.

After installation in the field, time shall be allowed for equilibration of the psychrometers with the surroundings. A few days before making readings to determine background water potentials is generally adequate.

4. RECORDS MANAGEMENT

4.1 Lifetime

Documents and data generated from implementation of this procedure may include the following: water potential data, location data, which shall be recorded on, but not limited to scientific notebooks, computer hard-drives, or other electronic storage media.

Notebooks, forms, or other organized documentation shall be prepared, as appropriate, by the PI or a contributing investigator to record data from this procedure and shall include any information considered by the originator to be pertinent. All documents shall be signed (or initialed) and dated by the investigator as entries are made. Any revisions shall be lined out, initialed, and dated. Notations shall be made in ink and submitted in legible photocopy form.

Calibration data shall be entered, signed, and dated, in a scientific notebook or other organized documentation permitted by YAP-12.3Q.

4.2 Non-Permanent

None

4.3 Controlled Documents

This Technical Implementing Procedure

4.4 Records Center Documents

Records associated with this procedure shall be submitted to RPC in accordance with AP-17.1Q, *Record Source Responsibility for Inclusionary Records*.

5.0 RESPONSIBILITIES

5.1 The Principal Investigator (PI) is responsible for assuring full compliance with this procedure and providing training thereof. The PI is responsible for overseeing and coordinating TIP preparation, review, distribution, revision, and recommendation of rescission.

5.2 Staff Members involved in the psychrometer calibration and data collection activities described herein are responsible for following this procedure and turning over related documentation to the Records Coordinator for submittal to the RPC in accordance with AP-17.1Q. Related data shall be turned over to Technical Data Coordinator for submittal to the Technical Data Management System (TDMS) in accordance with and AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System*.

6. ACRONYMS AND DEFINITIONS

6.1 Acronyms

AP	OCRWM Administrative Procedure
EA	Engineering Assurance
LBNL	Lawrence Berkeley National Laboratory
M&TE	Measuring and Test Equipment
NCR	Nonconformance Report
NIST	National Institute of Standards and Technology
OCR	Out of Calibration Report
OCRWM	Office of Civilian Radioactive Waste Management
OQA	Office of Quality Assurance
PI	Principal Investigator
RPC	Record Processing Center
QIP	Quality Implementing Procedure
QSL	Qualified Suppliers List
TIP	Technical Implementing Procedure

TDMS	Technical Data Management System
YAP	YMP Administrative Procedure
YMP	Yucca Mountain Site Characterization Project

6.2 Definitions

Water Potential: Is defined in terms of the energy status of the water. Water potential is the energy required to remove water reversibly and isothermally from a standard reference state to the system under consideration. The reference state chosen is usually pure, free water at the same temperature as water in the system and at a pressure of one standard atmosphere.

Calibration: The process of establishing the accuracy of a standard or measuring device, which may require resetting parameters on the device to improve its accuracy.

Staff Member: Any scientist, engineer, research or technical associate, technician, or student research assistant performing quality-affecting work for YMP-LBNL.

Technical Implementing Procedure: Each TIP describes YMP-LBNL technical tasks that (1) are repetitive, (2) are standardized, and (3) can return different results if deviation from the sequence of steps occur.

7. REFERENCES .

Brown, R. W. 1970. Measurement of Water Potential with Thermocouple Psychrometers: Construction and Applications. USDA Forest Service Research Paper INT-80.

Brown, R. W. and Collins, J. M. 1980. A screen-caged thermocouple psychrometer and calibration chamber for measurements of plant and soil water potential. Agron. J. 72:851-854.

Campbell E. C., Campbell, G. S. and Barlow, W. K. 1973. A dew hygrometer for water potential measurements ., Agric. Meteteorol. 12:113-121.

Savage, M. J., Wiebe, H.H. and Cass, A. 1983. In situ field measurement of water potential using thermocouple psychrometers. Plant Physio., 73: 609-613.

Savage, M.J., and Cass, A. 1984. Measurement of Water Potential using in situ thermocouple hygrometer, Advances in Agronomy (37) 73-126.

Spanner, D. C. 1951. The Peltier effect and its use in the measurement of suction pressure, J. Exp. Bot. 2:145-168.

DOE/RW-0333P, *Quality Assurance Requirements and Description (QARD)*

AP-17.1Q, *Record Source Responsibility for Inclusionary Records*

AP-SIII.1Q, *Scientific Notebooks*

AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System*

YAP-12.3Q, *Control of Measuring and Test Equipment and Calibration Standards*

YMP-LBNL-QIP-5.2, *Preparing Development Plans & Quality/Technical Implementing Procedures*

YMP-LBNL-QIP-SV.0, *Control of the Electronic Management of Data*

8. ATTACHMENTS

Attachment 1: Connection to CR7 using the A3497 Psychrometer Cooling Current Interface

Attachment 2: Example of program written to measure 10 psychrometers using the CR7 data logger

Attachment 3: Output from psychrometer measurement

Attachment 4: Instruction sheet for Wescor psychrometers

9. REVISION HISTORY

09/30/98 Revision 0, Modification 0

This is the initial issue of this procedure, a derivative of a scientific notebook procedure/methodology prepared by R. Salve. It was part of the scientific investigation in the scientific notebook YMP-LBNL-JW-1.2.

01/21/00 Revision 1, Modification 0

Revised procedure to meet the changes made to YAP-12.3Q requirements that were missing in Rev.0 of this procedure and to incorporate references to other applicable APs, YAPs and QIPs.

Deleted responsibilities for staff members not directly responsible for implementing this procedure and references to vendor manuals.

8/25/00 Revision 2, Modification 0

Revised procedure to include how calibration coefficients and water potential values are obtained from the raw voltage values. Revised Attachment 2 to describe the measurements of 10 psychrometers instead of 56. Removed Table 1 "Water Potentials of NaCl" from Attachment 4.

10. APPROVAL

Signature on file

Preparer: Rohit Salve — Date

Signature on file

Technical Reviewer: Tim Kneafsey — Date

Signature on file

Technical Reviewer: Peter Persoff — Date

Signature on file

EA Reviewer: Nancy Aden-Gleason — Date

Signature on file

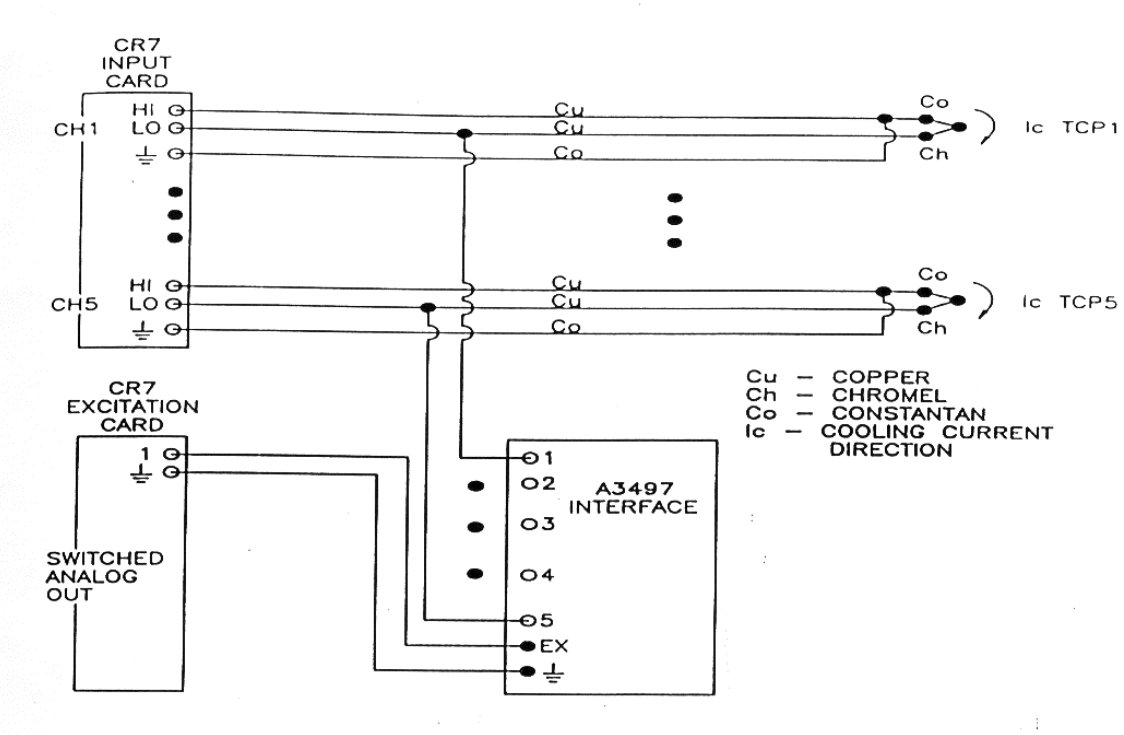
OQA Concurrence: Stephen Harris — Date

Signature on file

Principal Investigator: Joseph Wang — Date

Signature on file

Project Manager: Gudmundur Bodvarsson — Date



Connection to CR7 using the A3497 Phychrometer Cooling Current Interface

EXAMPLE OF A PROGRAM
ATTACHMENT 2

This is an example of a program written to measure 10 psychrometers using the CR7 data logger.

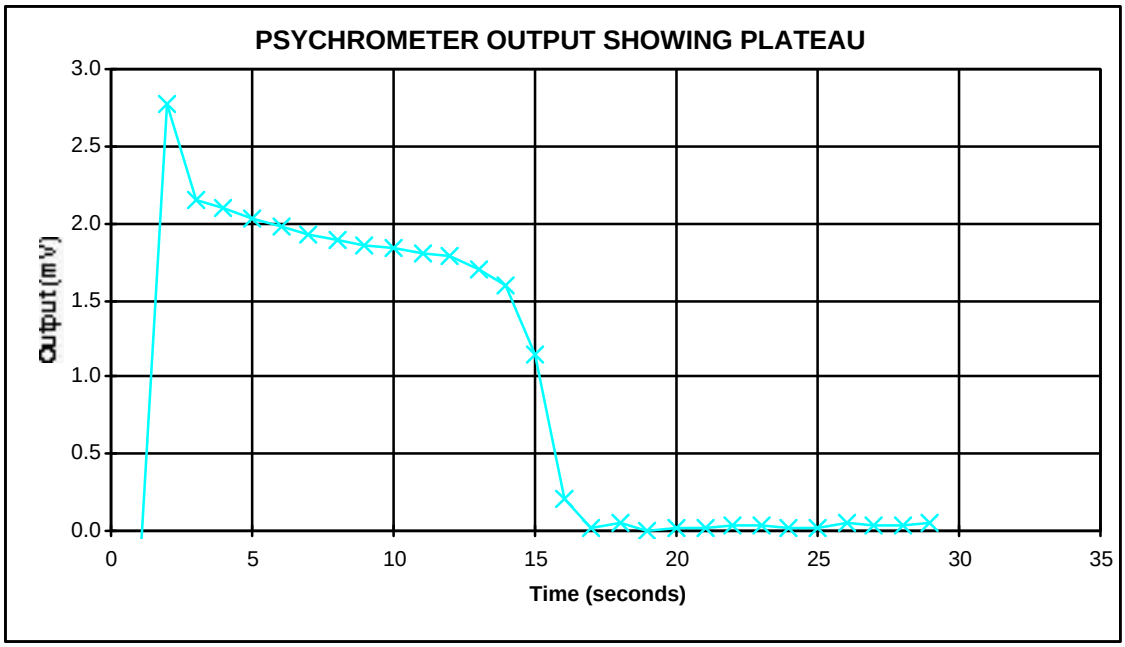
```
;{CR7}
;Psychrometer program written to read 10 psychrometers

;Program takes 28 readings in the dewpoint mode
;Output starts with Panel temperature, logger battery
;then data from individual psychrometers and transducers.
;Each psychrometer output includes temperature,
;offset (i.e. input-read), and 28 microvolt readings
;made in the psych. mode.



*Table 1 Program
  01: 5400      Execution Interval (seconds)


1:  Panel Temperature (P17)
 1: 1         In Card
 2: 1         Loc [ Panel_T   ]


2:  Battery Voltage (P10)
 1: 2         Loc [ Battert_V ]


3:  IF (X<=>F) (P89)
 1: 2         X Loc [ Battert_V ]
 2: 4         <
 3: 11.9      F
 4: 0         Go to end of Program Table

;Portion of program to read first 5 psychrometers

4:  Thermocouple Psychrometer (P25)
 1: 5         Psychrometers per A3497
 2: 3         Loc [ Psy1_1    ]
 3: 1         Reference Temperature Loc [ Panel_T   ]
 4: 2         2=Measure HI WRT GND, 1=LO
 5: 1         In Card
 6: 1         In Chan
 7: 2         Ex Card
 8: 1         Ex Chan
 9: -1500     mV Excitation
10: 0         Heating (time units = 0.01 sec)
11: 0         Delay before 0 measurement
12: 1000      Cooling Duration
13: 0         Delay before wet bulb measurement
14: 100       Delay between wet bulb measurement
15: 28        Wet bulb measurements per psychrometer
```

```
;Portion of program to read next 5 psychrometers

5:  Thermocouple Psychrometer (P25)
 1: 5        Psychrometers per A3497
 2: 153      Loc [ Psy2_1    ]
 3: 1        Reference Temperature Loc [ Panel_T   ]
4: 2        2=Measure HI WRT GND, 1=LO
 5: 1        In Card
 6: 6        In Chan
 7: 2        Ex Card
 8: 2        Ex Chan
 9: -1500    mV Excitation
10: 0        Heating (time units = 0.01 sec)
11: 0        Delay before 0 measurement
12: 1000     Cooling Duration
13: 0        Delay before wet bulb measurement
14: 100      Delay between wet bulb measurement
15: 28       Wet bulb measurements per psychrometer


;Instructions to output data.


6:  Do (P86)
 1: 10       Set Output Flag High


7:  Real Time (P77)
 1: 1110     Year,Day,Hour/Minute (midnight = 0000)


8:  Sample (P70)
 1: 1        Reps
 2: 1        Loc [ Panel_T   ]


9:  Sample (P70)
 1: 1        Reps
 2: 2        Loc [ Battert_V ]



10:  Do (P86)
 1: 10       Set Output Flag High

11:  Sample (P70)
 1: 30       Reps
 2: 3        Loc [ Psy1_1    ]

12:  Do (P86)
 1: 10       Set Output Flag High

13:  Sample (P70)
 1: 30       Reps
 2: 33       Loc [ Psy1_31   ]
```

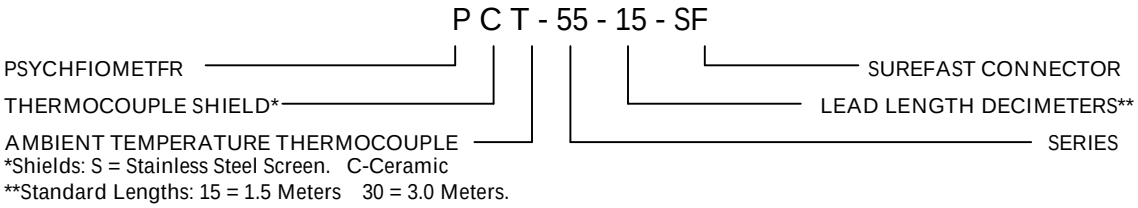
```
14:  Do (P86)
 1: 10       Set Output Flag High

15:  Sample (P70)
 1: 30       Reps
 2: 63       Loc [ Psy1_61   ]
16:  Do (P86)
 1: 10       Set Output Flag High

17:  Sample (P70)
 1: 30       Reps
 2: 93       Loc [ Psy1_91   ]
18:  Do (P86)
 1: 10       Set Output Flag High

19:  Sample (P70)
 1: 30       Reps
 2: 123      Loc [ Psy1_121  ]


20:  Do (P86)
 1: 10       Set Output Flag High

21:  Sample (P70)
 1: 30       Reps
 2: 153      Loc [ Psy2_1    ]

22:  Do (P86)
 1: 10       Set Output Flag High

23:  Sample (P70)
 1: 30       Reps
 2: 183      Loc [ Psy2_31   ]
24:  Do (P86)
 1: 10       Set Output Flag High

25:  Sample (P70)
 1: 30       Reps
 2: 213      Loc [ Psy2_61   ]
26:  Do (P86)
 1: 10       Set Output Flag High

27:  Sample (P70)
 1: 30       Reps
 2: 243      Loc [ Psy2_91   ]
28:  Do (P86)
 1: 10       Set Output Flag High

29:  Sample (P70)
 1: 30       Reps
 2: 273      Loc [ Psy2_121  ]



30:  Serial Out (P96)
 1: 30       SM192/SM716/CSM1
```

```
*Table 2 Program
  02: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

ATTACHMENT 3
PSYCHROMETER OUTPUT



Wescor peltier cooled psychrometers are available with either stainless steel screen shields or porous ceramic shields. Other options such as lead length and connectors are explained in the diagram below.



*Shields: S = Stainless Steel Screen. C-Ceramic
**Standard Lengths: 15 = 1.5 Meters 30 = 3.0 Meters.

The ceramic shield can be removed by gently pulling it away from the silicone rubber boot which holds it in place. The boot must be held firmly just below the shield so that the mount and contact pins are not pulled away from the leads while removing the shield. If difficulty occurs in removing the shield the silicone boot can be pushed back toward the leads to facilitate the removal. The stainless steel screen is held in place by heat shrink tubing which has a meltable liner. The liner is an adhesive which holds the screen firmly in place. The stainless steel screen is not removable.

Cleaning the Psychrometers

The psychrometer thermocouple, mount and screen should be thoroughly cleaned after calibration and before being used for measurements.

Ceramic shield psychrometers:

The ceramic shield should be removed and the exposed thermocouple and teflon mount should be rinsed with a detergent or ammonia solution or another solvent and then rinsed with pure deionized water. Water remaining on the thermocouple after rinsing should be blown away with blow clean or a low pressure (40 psi or less) burst of clean dry air or another clean gas such as nitrogen. Swishing the exposed thermocouple in a container of pure hot water will often remove stubborn contaminants. The ceramic shield can be cleaned by letting it stand in pure distilled water, rinsing it, and blowing the excess water away.

Stainless steel screen shield psychrometers:

The stainless steel screen psychrometers can be cleaned by rinsing them vigorously in distilled deionized water. The water inside the shield should be

blown away by a blast of clean dry air. The air pressure can be higher than that use when drying an exposed thermocouple. Water can also be forced into the screen shield by placing the nozzle of a plastic squeeze bottle directly on the screen and forcing the water from the bottle into the screen. Again the water inside should be blown away as above.

Connecting to the meter The psychrometers have an outer insulation of white PVC. Enclosed are an aluminized mylar shield with a bare drain wire two insulated copper conductors and an insulated constantan conductor. The cutaway view of a ceramic shield psychrometer shows the color code and connections for each wire.

The color coding on the three insulated wires matches the color coding of the binding posts on the HR-33T. The bare wire is the drain wire for the shield. It is not usually necessary to connect this wire but under some conditions connecting this wire to case ground will reduce noise pick up.

If the cable and the measurement instrument has SUREFAST connectors the connection is accomplished by pushing the cable connector into the receptacle until it is firmly in place.

Calibration

The output of the soil psychrometer is approximately 0.47 microvolts per bar in the psychrometric mode and 0.75 microvolts per bar in the dewpoint mode.

Wescor psychrometers are calibrated in a 0.5514 molal (1,000 mmol/kg) NaCl solution and the calibration curve for this point is enclosed. Although this is a single point calibration the relationship of water potential to the microvolt output is very nearly linear over the range of psychrometer measurements. Further calibrations as described below are recommended. The psychrometers should always be thoroughly cleaned following any calibration.

Method of calibration Calibrations using 3 or 4 different water potentials should be made and the data obtained plotted on a graph of microvolt output vs. water potential. A straight line representing the best fit of the points should be determined. The slope of this straight line is the responsively of the psychrometer in microvolts per bar.

Immerse the psychrometers in a known concentration of NaCl or another solution having a known water potential. Allow sufficient time for vapor equilibrium to occur within the shield. Ceramic shield psychrometers take about two hours and

stainless steel screen psychrometers take about one hour for equilibration to occur. The container of calibration solution should be placed in a well insulated box free from any temperature fluctuations. Accurate measurements for calibration or for data are difficult if temperature gradients are present.

Table 1 gives the water potential in bars of solutions of NaCl at various temperatures. A 1 molal solution can be made by dissolving 1 gm molecular weight of NaCl (58.44 gms) in 1,000 gms of pure distilled water. Other molalities can be obtained by using a proportional amount of NaCl in 1,000 gms of water.

Temperature correction: There are two methods of water potential measurements. These are the dew point (hygrometric) and the wet bulb (psychrometric). These methods are explained and details of the procedure followed are in the HR-33T manual. If the dew point Method is used property, no temperature correction is necessary.

The psychrometric method output is highly dependent on the temperature. The standard procedure used by most researchers is to adjust all calibrations and measurements to a temperature of 25°C. The following formula makes this adjustment:

$$\text{CORRECTED READING} = \frac{\text{MEASURED READING}}{(0.325 + 0.027\,^{\circ}\text{T})}$$

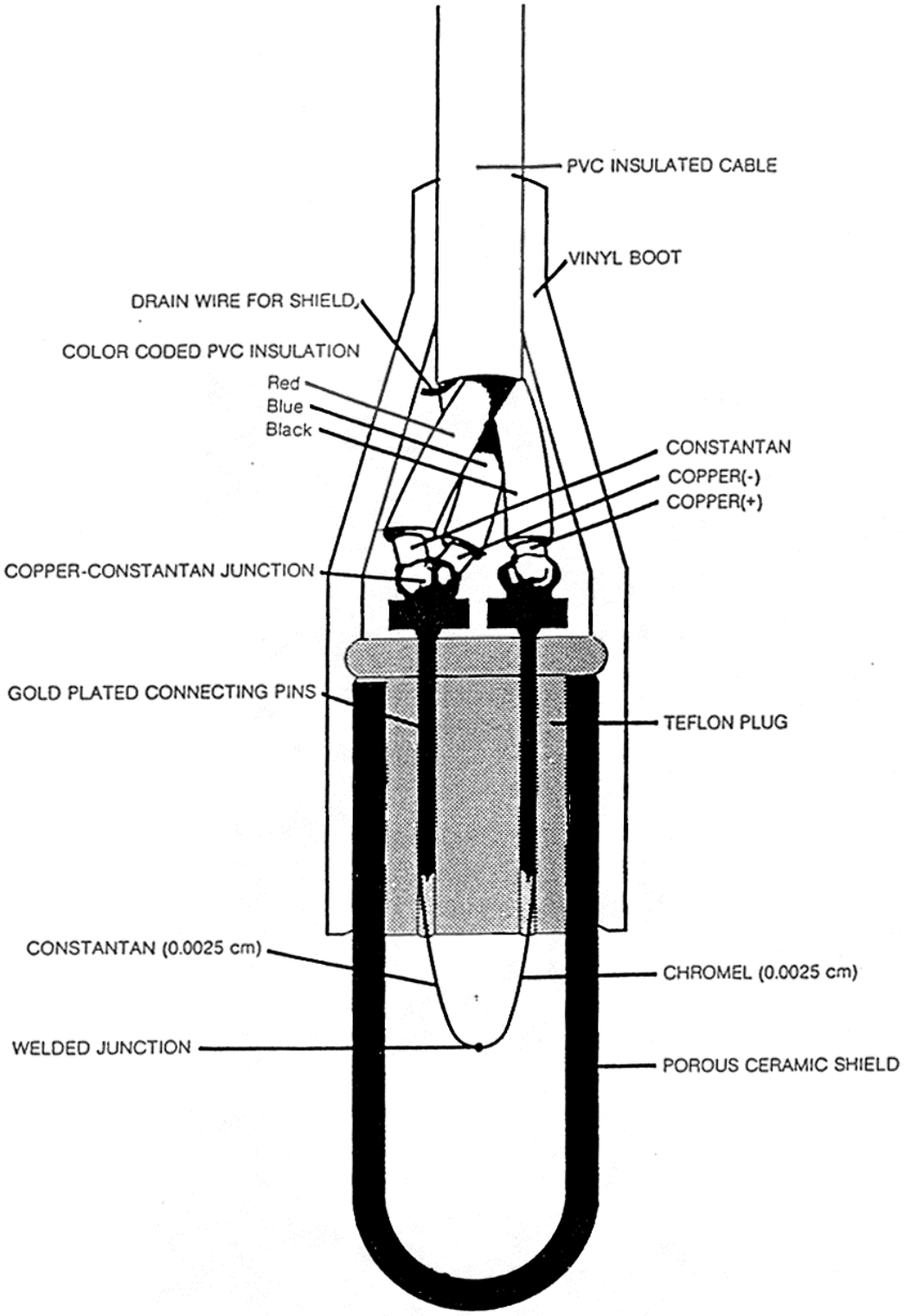
T is the temperature in celsius at which the reading was made.

Installation:

The soil psychrometers should be placed in the soil so that the axis of the psychrometer is parallel with the surface of the soil. This will reduce the effect of temperature gradients caused by heat flux going into the soil during the day and coming from the soil during the night.

If the psychrometers are close to the surface of the soil it may be impossible to get valid data during the part of the day when the temperature gradients are large. The temperature gradient can be determined by measuring the psychrometer output before cooling the junction. The difference between the signal when the amplifier of the reading meter is shorted and when R is open to the psychrometer (READ position) is the offset and is a measure of the temperature gradient. If the temperature gradient outputs more than a few microvolts it may affect the accuracy of the readings.

After the psychrometer is placed in the soil it is advisable to wait a day before making readings to determine the water potential. This allows the soil to return to equilibrium as well as allowing the psychrometer to equilibrate with the soil. Direct contact with the soil to be measured is not necessary but will accelerate the equilibration of the psychrometer. The soil Itself will help the temperature to be stable, since it is a fair insulator, but if the soil air interface is at a different temperature the soil will maintain a temperature gradient for some distance into the soil. It is very difficult to get good measurements from soil in small containers in a greenhouse where the temperature fluctuates widely. Sometimes it is necessary to use insulation around the containers to equalize the temperature through the soil.



Peltier Psychrometer / Hygrometer with porous ceramic thermocouple shield